

FIG. 1A

POLARIZATION  
DIRECTION

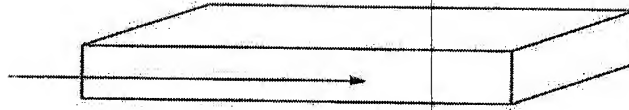


FIG. 1B

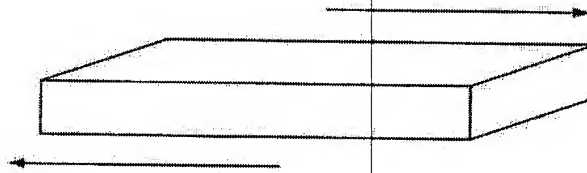


FIG. 2

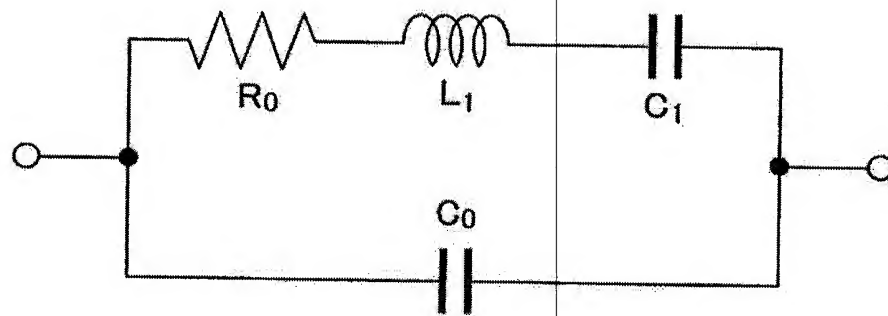


FIG. 3

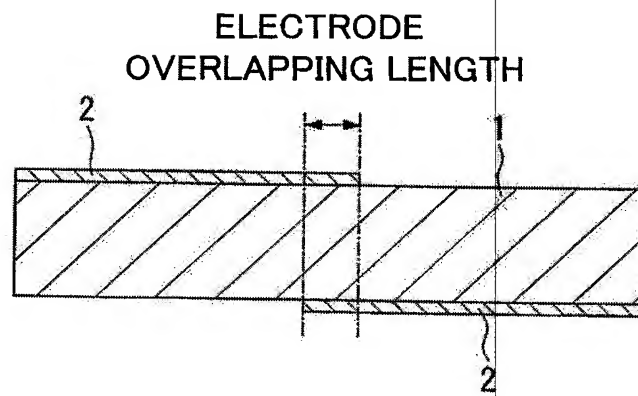
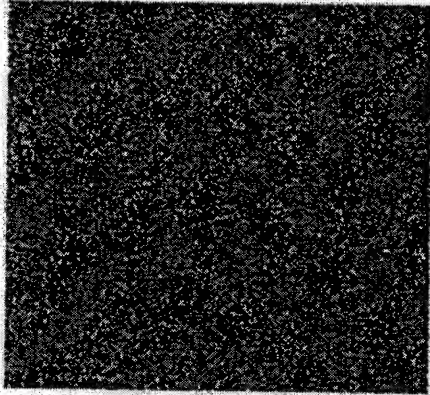


FIG. 4

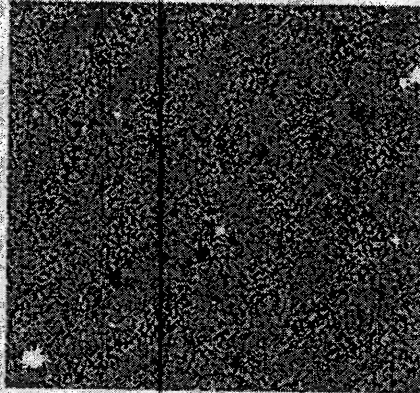
| SPECIMEN<br>No. | ADDITIVE                                |                           | MAIN COMPONENT<br>$Pb_{\alpha}[(Mn_{1/3}Nb_{2/3})_xTi_yZr_z]O_3$<br>(x+y+z=1) |            |            |            | ELECTRIC<br>PROPERTIES<br>$Q_{max}$ | MECHANICAL<br>STRENGTH<br>$\sigma_{b3}$<br>(N/mm <sup>2</sup> ) | HEAT<br>RESISTING<br>PROPERTIES<br>  $\Delta F_0$  <br>(%) | AL-<br>CONTAINING<br>PHASE |
|-----------------|---|---------------------------|---|------------|------------|------------|-------------------------------------|---|--|----------------------------|
|                 | Al <sub>2</sub> O <sub>3</sub><br>(wt%) | SiO <sub>2</sub><br>(wt%) | $\alpha$<br>(mol)   | x<br>(mol) | y<br>(mol) | z<br>(mol) |                                     |   |  |                            |
| 1               | 0.1                                     |                           |   |            |            |            | 120                                 | 155   | 0.11   | x                          |
| 2               | 0.3                                     |                           |   |            |            |            | 135                                 | 172   | 0.07   | O                          |
| 3               | 0.5                                     | 0.02                      | 0.99  | 0.10       | 0.53       | 0.37       | 136                                 | 179   | 0.08   | O                          |
| 4               | 0.7                                     |                           |   |            |            |            | 130                                 | 192   | 0.07   | O                          |
| 5               | 1.0                                     |                           |   |            |            |            | 133                                 | 192   | 0.07   | O                          |

FIG. 5

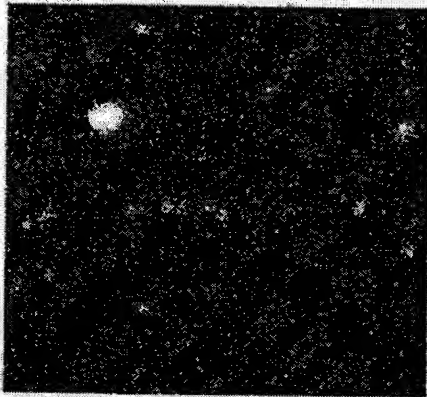
SPECIMEN No. 1



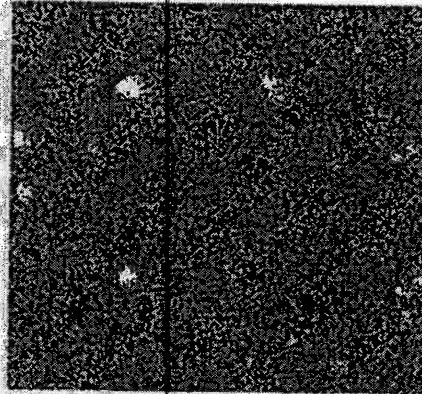
SPECIMEN No. 2



SPECIMEN No. 3



SPECIMEN No. 4



SPECIMEN No. 5

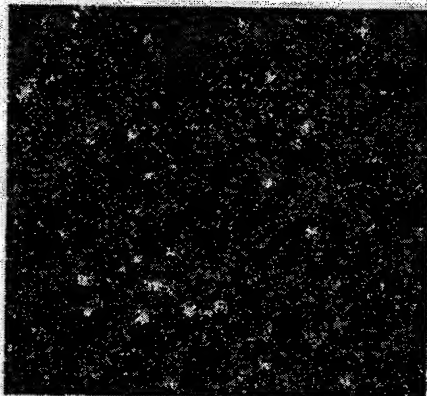


FIG. 6

| SPECIMEN<br>No. | ADDITIVE ( $\beta$ ) |                  | MAIN COMPONENT<br>$Pb_a[(Mn_{1/3}Nb_{2/3})_xTi_yZr_z]O_3$<br>( $x+y+z=1$ ) |            |            |            | ELECTRIC<br>PROPERTIES<br>$Q_{max}$ | HEAT<br>RESISTING<br>PROPERTIES<br>$ \Delta k_{15} $<br>(%) | TEMPERATURE<br>CHARACTERISTICS |                             |      |
|-----------------|----------------------|------------------|--|------------|------------|------------|-------------------------------------|---|--------------------------------|-----------------------------|------|
|                 | $Al_2O_3$<br>(wt%)   | $SiO_2$<br>(wt%) | $\alpha$<br>(mol)  | x<br>(mol) | y<br>(mol) | z<br>(mol) |                                     |   | $ \Delta F_0(-40^{\circ}C) $   | $ \Delta F_0(85^{\circ}C) $ |      |
| 6               | 0.01                 | 0.02             | 0.998  | 0.10       | 0.51       | 0.39       | 135                                 | 3.9   | 0.18                           | 0.08                        |      |
| 7               | 0.02                 |                  |  |            |            |            | 125                                 | 3.0   | 0.16                           | 0.05                        |      |
| 8               | 0.10                 |                  |  |            |            |            | 128                                 | 2.9   | 0.21                           | 0.10                        |      |
| 9               | 0.50                 |                  |  |            |            |            | 145                                 | 1.9   | 0.27                           | 0.14                        |      |
| 10              | 1.00                 |                  |  |            |            |            | 110                                 | 3.0   | 0.33                           | 0.19                        |      |
| 11              | 0.10                 |                  |  |            |            |            |                                     | 121   | 2.3                            | 0.09                        | 0.05 |
| 12              | 0.30                 |                  |  |            |            |            |                                     | 135   | 2.3                            | 0.04                        | 0.03 |
| 13              | 0.50                 |                  |  |            |            |            |                                     | 136   | 2.4                            | 0.04                        | 0.07 |
| 14              | 0.70                 |                  |  |            |            |            |                                     | 121   | 2.3                            | 0.03                        | 0.10 |
| 15              | 1.00                 |                  | 0.990  |            |            | 0.53       | 0.37                                | 133   | 2.2                            | 0.04                        | 0.07 |
| 16              | 1.50                 |                  |  |            |            |            |                                     | 122   | 2.2                            | 0.02                        | 0.06 |
| 17              | 2.00                 |                  |  |            |            |            |                                     | 121   | 2.1                            | 0.02                        | 0.10 |
| 18              | 3.00                 |                  |  |            |            |            |                                     | 104   | 2.4                            | 0.00                        | 0.09 |
| 19              | 10.00                |                  |  |            |            |            |                                     | 73  | 2.8                            | 0.01                        | 0.13 |

FIG. 7

| SPECI-<br>MEN No. | ADDITIVE           |                  | MAIN COMPONENT<br>$Pb_{\alpha}[(Mn_{1/3}Nb_{2/3})_xTi_yZr_z]O_3$<br>( $x+y+z=1$ ) |            |            |            | ELECTRIC<br>PROPER-<br>TIES<br>$Q_{max}$ | HEAT<br>RESISTING<br>PROPERTIES<br>$ \Delta k_{15} $<br>(%) | TEMPERATURE<br>CHARACTERISTICS |                             |
|-------------------|--------------------|------------------|---|------------|------------|------------|--|---|--------------------------------|-----------------------------|
|                   | $Al_2O_3$<br>(wt%) | $SiO_2$<br>(wt%) | $\alpha$<br>(mol)   | x<br>(mol) | y<br>(mol) | z<br>(mol) |  |   | $ \Delta F_0(-40^{\circ}C) $   | $ \Delta F_0(85^{\circ}C) $ |
| 20 *              | 0.5                | 0.02             | 0.990   | 0.02       | 0.56       | 0.42       | 29                                       | 1.1   | 0.24                           | 0.14                        |
| 21                |                    |                  |   | 0.04       | 0.58       | 0.38       | 81                                       | 0.9   | 0.11                           | 0.14                        |
| 22                |                    |                  |   |            | 0.56       | 0.40       | 85                                       | 1.0   | 0.25                           | 0.02                        |
| 23                |                    |                  |   |            | 0.55       | 0.41       | 117                                      | 1.4   | 0.29                           | 0.09                        |
| 24 *              |                    |                  |   |            | 0.54       | 0.42       | 108                                      | 1.4   | 0.54                           | 0.19                        |
| 25                |                    |                  |   | 0.06       | 0.56       | 0.38       | 95                                       | 1.1   | 0.09                           | 0.04                        |
| 26 *              |                    |                  |   |            | 0.52       | 0.42       | 177                                      | 1.5   | 1.10                           | 0.77                        |
| 27 *              |                    |                  |   | 0.08       | 0.59       | 0.33       | 98                                       | 1.5   | 0.28                           | 0.41                        |
| 28                |                    |                  |   |            | 0.54       | 0.38       | 112                                      | 1.7   | 0.11                           | 0.02                        |
| 29                |                    |                  |   | 0.09       | 0.55       | 0.36       | 114                                      | 1.8   | 0.03                           | 0.19                        |
| 30                |                    |                  |   |            | 0.54       | 0.37       | 119                                      | 1.8   | 0.05                           | 0.11                        |
| 31                |                    |                  |   |            | 0.53       | 0.38       | 124                                      | 1.5   | 0.13                           | 0.03                        |
| 32                |                    |                  |   |            | 0.52       | 0.39       | 154                                      | 1.8   | 0.24                           | 0.07                        |
| 33                |                    |                  |   | 0.10       | 0.58       | 0.32       | 81                                       | 1.7   | 0.23                           | 0.30                        |
| 34                |                    |                  |   |            | 0.54       | 0.36       | 147                                      | 2.1   | 0.02                           | 0.14                        |
| 35                |                    |                  |   |            | 0.53       | 0.37       | 146                                      | 1.8   | 0.05                           | 0.06                        |
| 36                |                    |                  |   |            | 0.52       | 0.38       | 158                                      | 1.7   | 0.14                           | 0.02                        |
| 37                |                    |                  |   |            | 0.51       | 0.39       | 183                                      | 1.6   | 0.25                           | 0.13                        |
| 38                |                    |                  |   | 0.11       | 0.53       | 0.36       | 135                                      | 2.7   | 0.00                           | 0.09                        |
| 39                |                    |                  |   |            | 0.52       | 0.37       | 127                                      | 1.9   | 0.07                           | 0.00                        |
| 40                |                    |                  |   |            | 0.51       | 0.38       | 163                                      | 2.0   | 0.16                           | 0.10                        |
| 41                |                    |                  |   |            | 0.50       | 0.39       | 170                                      | 2.0   | 0.27                           | 0.22                        |
| 42                |                    |                  |   | 0.12       | 0.58       | 0.30       | 80                                       | 2.2   | 0.29                           | 0.40                        |
| 43                |                    |                  |   |            | 0.56       | 0.32       | 98                                       | 2.3   | 0.20                           | 0.28                        |
| 44                |                    |                  |   |            | 0.50       | 0.38       | 177                                      | 2.6   | 0.13                           | 0.15                        |
| 45                |                    |                  | 0.995   | 0.09       | 0.55       | 0.36       | 128                                      | 1.3   | 0.00                           | 0.17                        |
| 46                |                    |                  |   |            | 0.54       | 0.37       | 131                                      | 1.6   | 0.08                           | 0.08                        |
| 47                |                    |                  |   |            | 0.53       | 0.38       | 129                                      | 1.2   | 0.14                           | 0.02                        |
| 48                |                    |                  |   |            | 0.52       | 0.39       | 154                                      | 0.8   | 0.26                           | 0.10                        |



FIG. 8

| SPECI-MEN No. | ADDITIVE           |                    |                    |                    |                    |                     |                  | MAIN COMPONENT  |            |            |            | ELECTRIC PROPER-TIES<br>$Q_{max}$ | HEAT RESISTING PROPERTIES<br>  $\Delta k_{15}$  <br>(%) | TEMPERATURE CHARACTERISTICS |      |
|---------------|--------------------|--------------------|--------------------|--------------------|--------------------|---------------------|------------------|---|------------|------------|------------|-----------------------------------|---|-----------------------------|------|
|               |                    |                    |                    |                    |                    |                     |                  | $Pb_{\alpha}[(Mn_{1-x}Nb_{2/3})_xTi_yZr_z]O_3$<br>( $x+y+z=1$ ) |            |            |            |                                   |   |                             |      |
|               | $Al_2O_3$<br>(wt%) | $Ga_2O_3$<br>(wt%) | $Ta_2O_5$<br>(wt%) | $Sc_2O_3$<br>(wt%) | $In_2O_3$<br>(wt%) | $^{33}O_3$<br>(wt%) | $SiO_2$<br>(wt%) | $\alpha$<br>(mol)   | x<br>(mol) | y<br>(mol) | z<br>(mol) | $\Delta F_0(-40^{\circ}C)$        | $\Delta F_0(85^{\circ}C)$                               |                             |      |
| 49            | -                  | 0.02               | -                  | -                  | -                  | -                   | 0.02             | 1.000   | 0.10       | 0.51       | 0.39       | 141                               | 2.2   | 0.40                        | 0.25 |
| 50            | -                  | 0.10               | -                  | -                  | -                  | -                   |                  | 1.000   | 0.10       | 0.51       | 0.39       | 145                               | 2.0   | 0.35                        | 0.23 |
| 51            | -                  | -                  | 0.50               | -                  | -                  | -                   |                  | 1.000   | 0.10       | 0.51       | 0.39       | 166                               | 2.7   | 0.12                        | 0.07 |
| 52            | -                  | -                  | 0.50               | -                  | -                  | -                   |                  | 0.995   | 0.09       | 0.55       | 0.36       | 107                               | 2.8   | 0.15                        | 0.30 |
| 53            | -                  | -                  | 0.50               | -                  | -                  | -                   |                  | 0.995   | 0.09       | 0.53       | 0.38       | 119                               | 1.9   | 0.03                        | 0.17 |
| 54            | -                  | -                  | 0.50               | -                  | -                  | -                   | 0.02             | 0.995   | 0.09       | 0.52       | 0.39       | 140                               | 1.6   | 0.05                        | 0.09 |
| 55            | -                  | -                  | -                  | 0.02               | -                  | -                   |                  | 0.990   | 0.10       | 0.51       | 0.39       | 147                               | 2.9   | 0.25                        | 0.12 |
| 56            | -                  | -                  | -                  | 0.10               | -                  | -                   |                  | 0.990   | 0.10       | 0.51       | 0.39       | 138                               | 2.7   | 0.30                        | 0.17 |
| 57            | 0.45               | -                  | -                  | -                  | 0.02               | -                   |                  | 0.990   | 0.10       | 0.51       | 0.39       | 131                               | 2.2   | 0.25                        | 0.15 |
| 58*           | -                  | -                  | -                  | -                  | -                  | 0.20                |                  | 1.000   | 0.10       | 0.51       | 0.39       | 81                                | 4.5   | 0.15                        | 0.13 |
| 59*           | -                  | -                  | -                  | -                  | -                  | 0.30                | 1.000            | 0.10  | 0.51       | 0.39       | 129        | 4.7                               | 0.09  | 0.04                        |      |
| 60*           | -                  | -                  | -                  | -                  | -                  | 0.50                | 1.000            | 0.10  | 0.51       | 0.39       | 120        | 4.2                               | 0.16  | 0.13                        |      |